NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM

Integral Experiments Accomplishments
IER-147 Results
Godiva Burst Characterization

Presented at the NCSP Technical Seminar at LLNL on March 18-19, 2015

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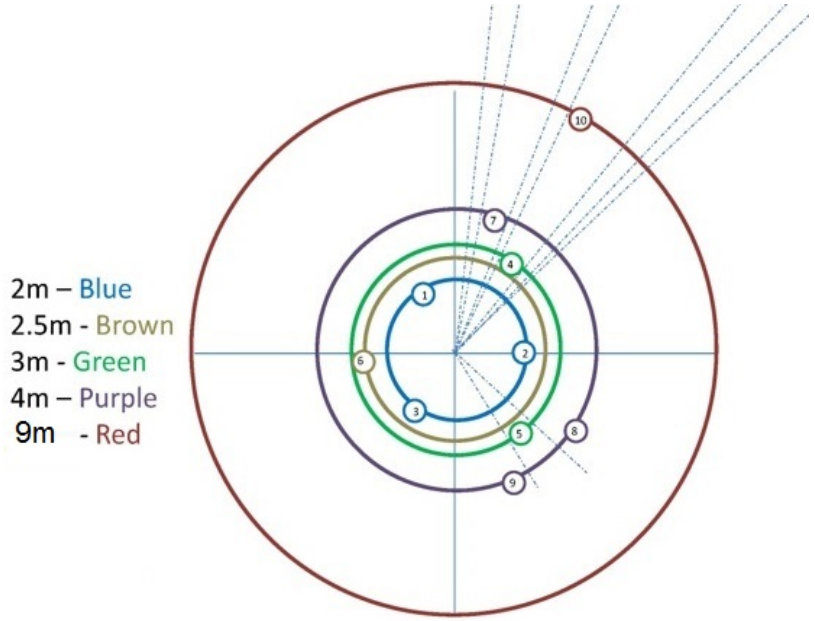
Collaborators

- **Atomic Weapons Establishment (Philip Angus, Leo Clark, Chris Wilson)**
  - Passive Bonner Sphere Spectrometer measurements(PBSS)
  - AWE NAD Lockett measurements
- **Lawrence Livermore National Laboratory (Clint Byington, Jennifer Burch, Kaylie Hammersborg, Dave Heinrichs, David Hickman, Becka Hudson, Todd Matz, Doug Mcavoy, Brian Musick, Scott Richardson, John Scorby, Gary Slavik, Carolyn Wong)**
  - LLNL NAD measurements
  - Gamma dose measurements
  - Work controls
  - Escort
  - Coordination and Assistance to all participants
- **Los Alamos National Laboratory (Joetta Goda, John Bounds & Crew)**
  - Godiva Operations
  - Retrieval of materials
- **NSTEC**
  - NSTEC NAD measurements
  - Contamination control and personnel dose monitoring
  - Assistance with retrieval of materials from Godiva and shipping to NAD LAB
- **Sandia National Laboratory (Elliot Leonard, Dan Ward)**
  - SNL NAD and other foil measurements
  - Gamma dose measurements

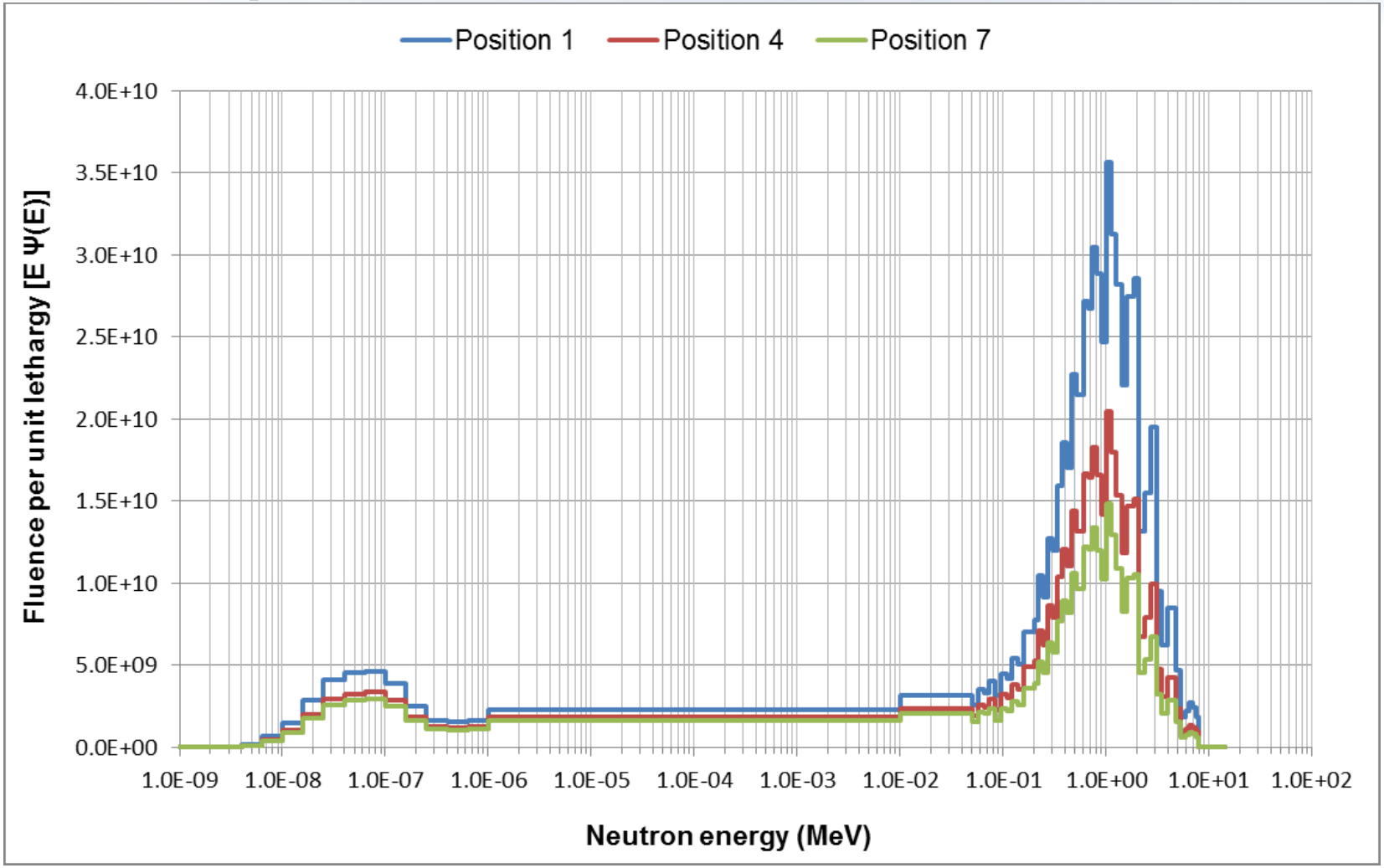
PBSS Measurements

- Nine bursts to irradiate 9 different diameter spheres at 9 reference locations (1-9) around Godiva.
- Spheres were rotated between reference locations.
- All bursts were approximately 70°C, with results normalized to 70°C.



Location of reference measurements for characterization of Godiva Burst Operations.

PBSS Spectral Results

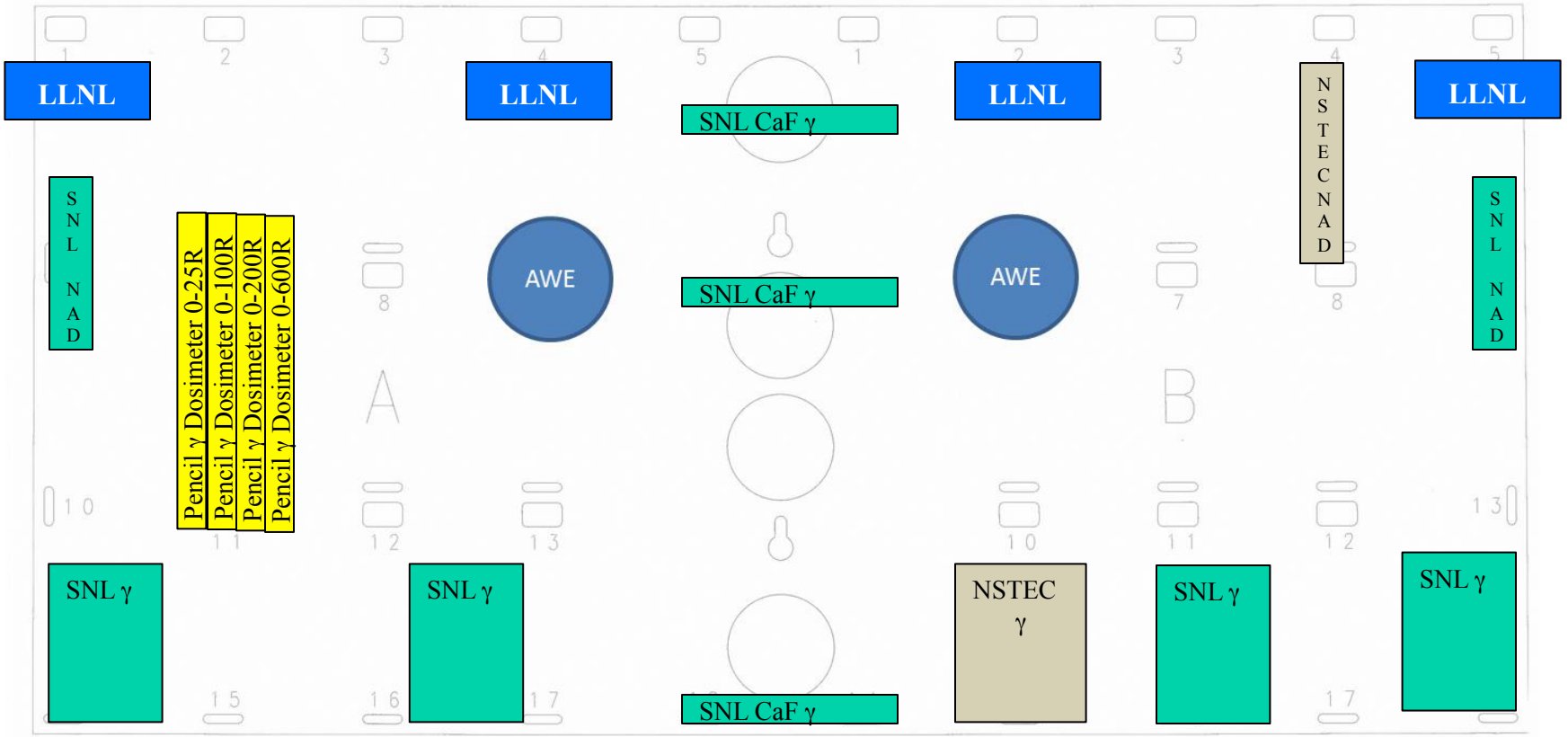


From: Wilson, C., Clark, L., Angus, P., Neutron spectrometry results from phase two of the Godiva-IV characterisation, AWE/NAS/RPG/ADS/CRIT/TR/004, November 2014.

NAD Exposures

- Three different burst exposures at 71.1, 136.9, 229.9°C
- 144 LLNL combination NAD/γ dosimeters at each exposure
- 48 AWE NADs exposed only to 71.1°C (for comparison to PBSS results)
- 35 SNL NADs exposed to 229.9°C Burst
- Single NSTEC NAD and γ dosimeter at each exposure level
- All results were normalized to 70, 140, and 230°C
- Only results from the top 2 exposure heights (nearest to the core height) are considered in this presentation unless otherwise noted

Dosimeter positions for 2m locations on the top plate (A/B)



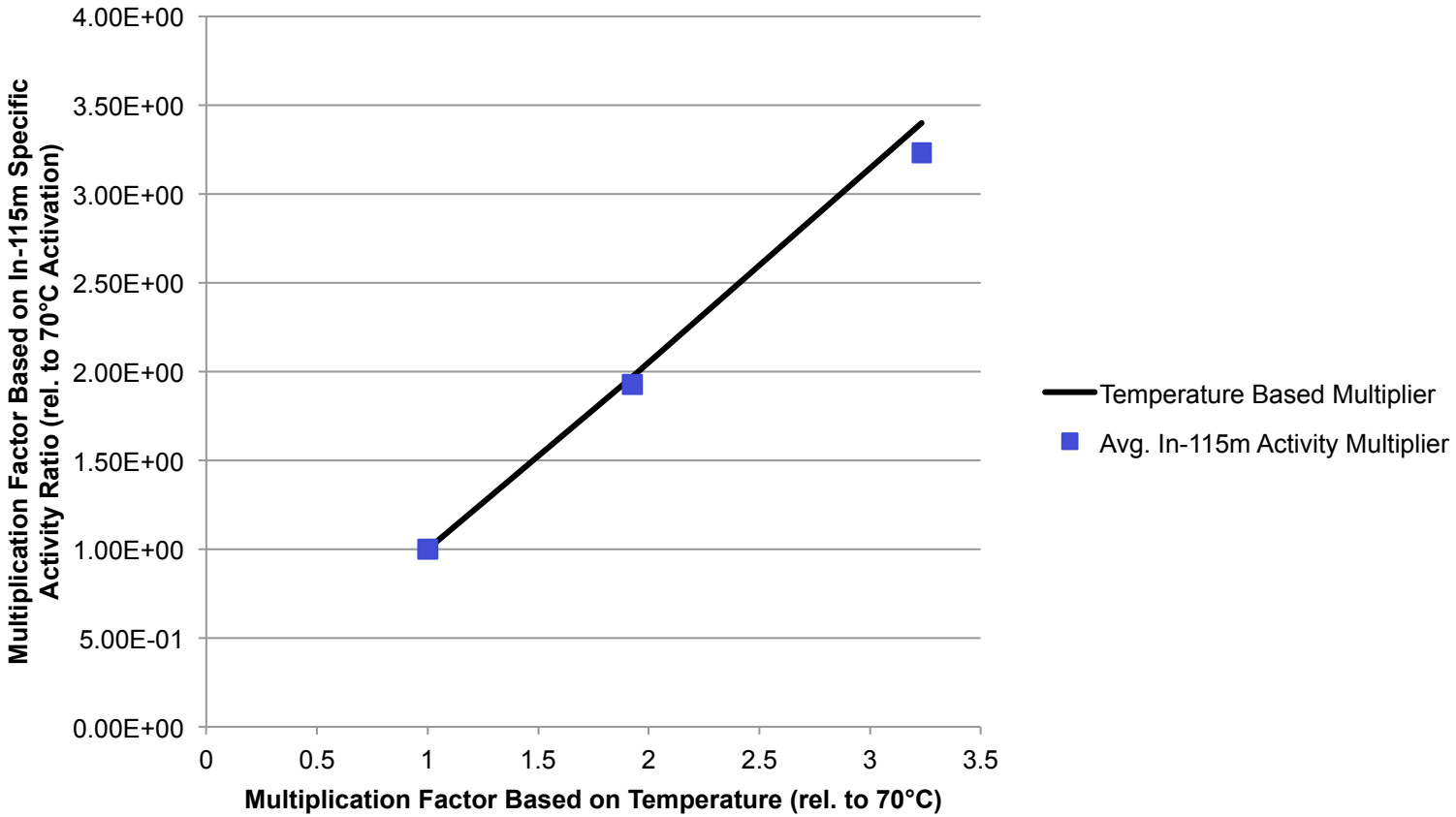
LLNL also deployed 5 fixed NADs for each burst

Total Fluence Comparison - 70°C (n cm^{-2})

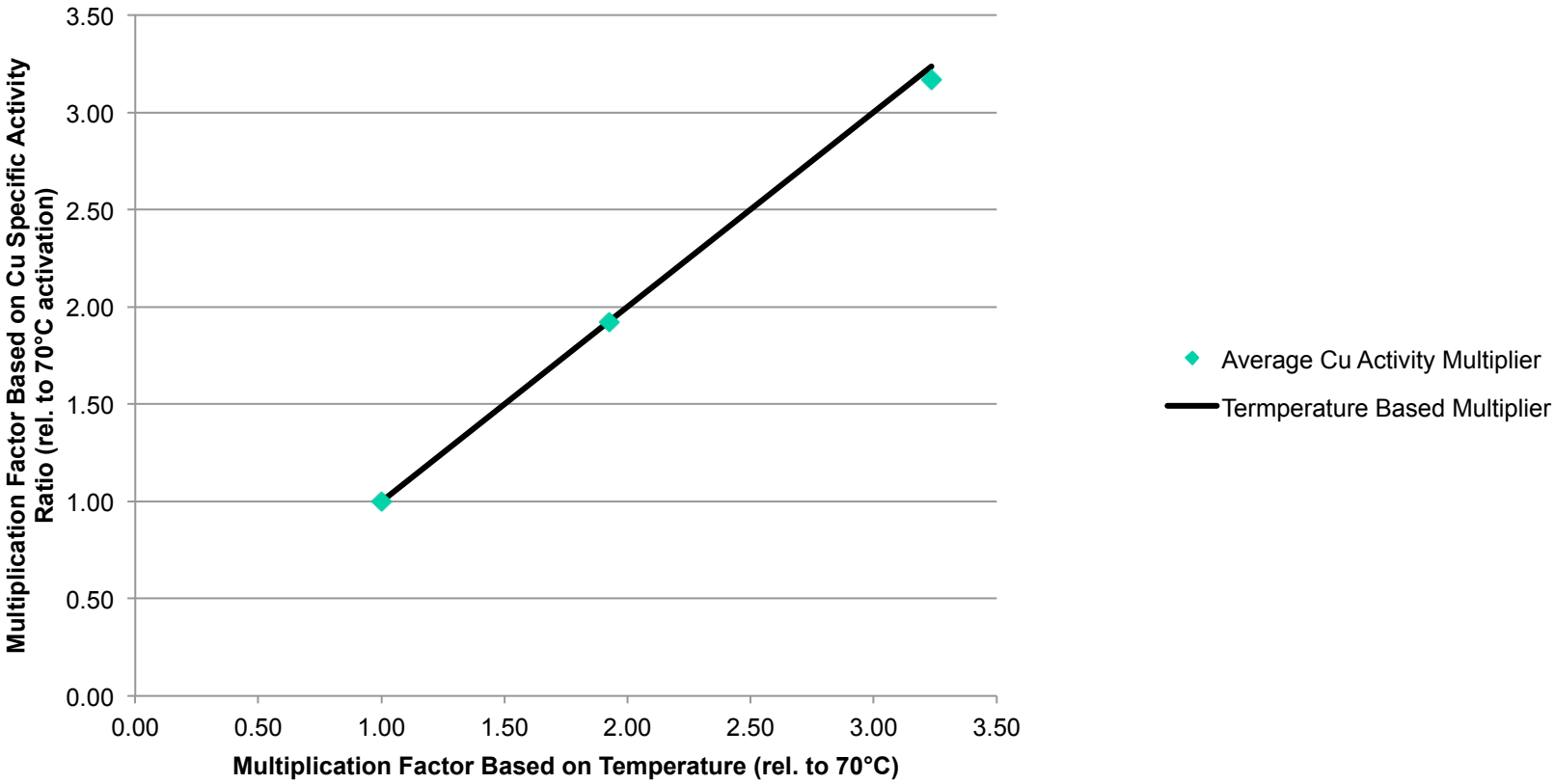
Position	PBSS	LLNL NAD	AWE NAD	SNL NAD[1]
1 (2m)	1.01E+11	9.45E+10	1.08E+11	5.39E+10
2 (2m)	9.61E+10	9.09E+10	1.03E+11	
3 (2m)	1.01E+11	9.52E+10	1.10E+11	
6 (2.5 m)	8.60E+10	9.45E+10	7.09E+10	
4 (3m)	6.56E+10	7.03E+10	5.82E+10	3.14E+10
5 (3m)	6.78E+10	7.52E+10	6.61E+10	
7 (4m)	5.11E+10	5.78E+10	3.93E+10	1.67E+10
8 (4m)	5.34E+10	6.89E+10	4.45E+10	
9 (4m)	5.47E+10	6.58E+10	4.69E+10	

[1] Fluence >1MeV

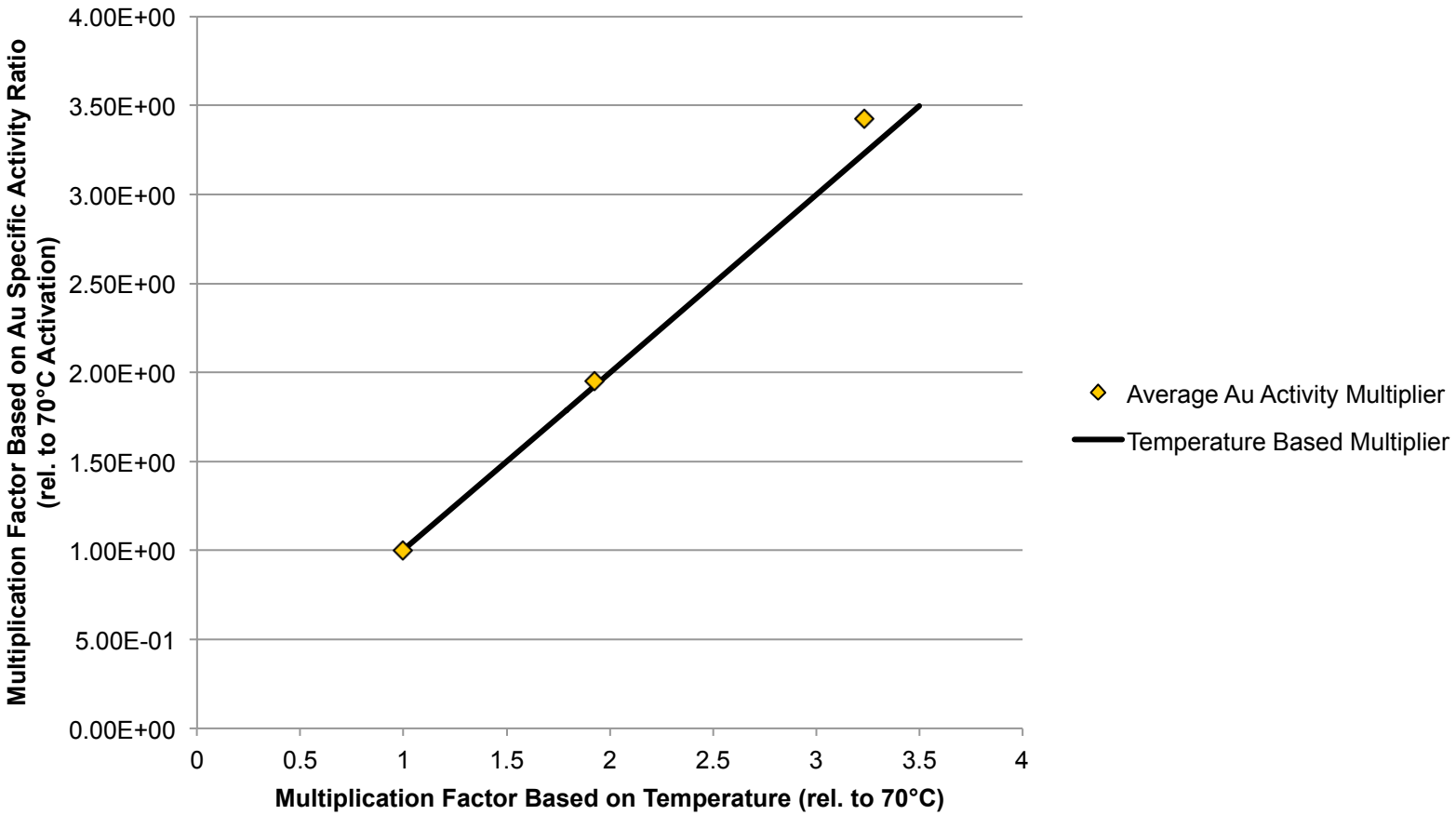
Correction of PBSS >1MeV neutron fluence for bursts greater than 70°C



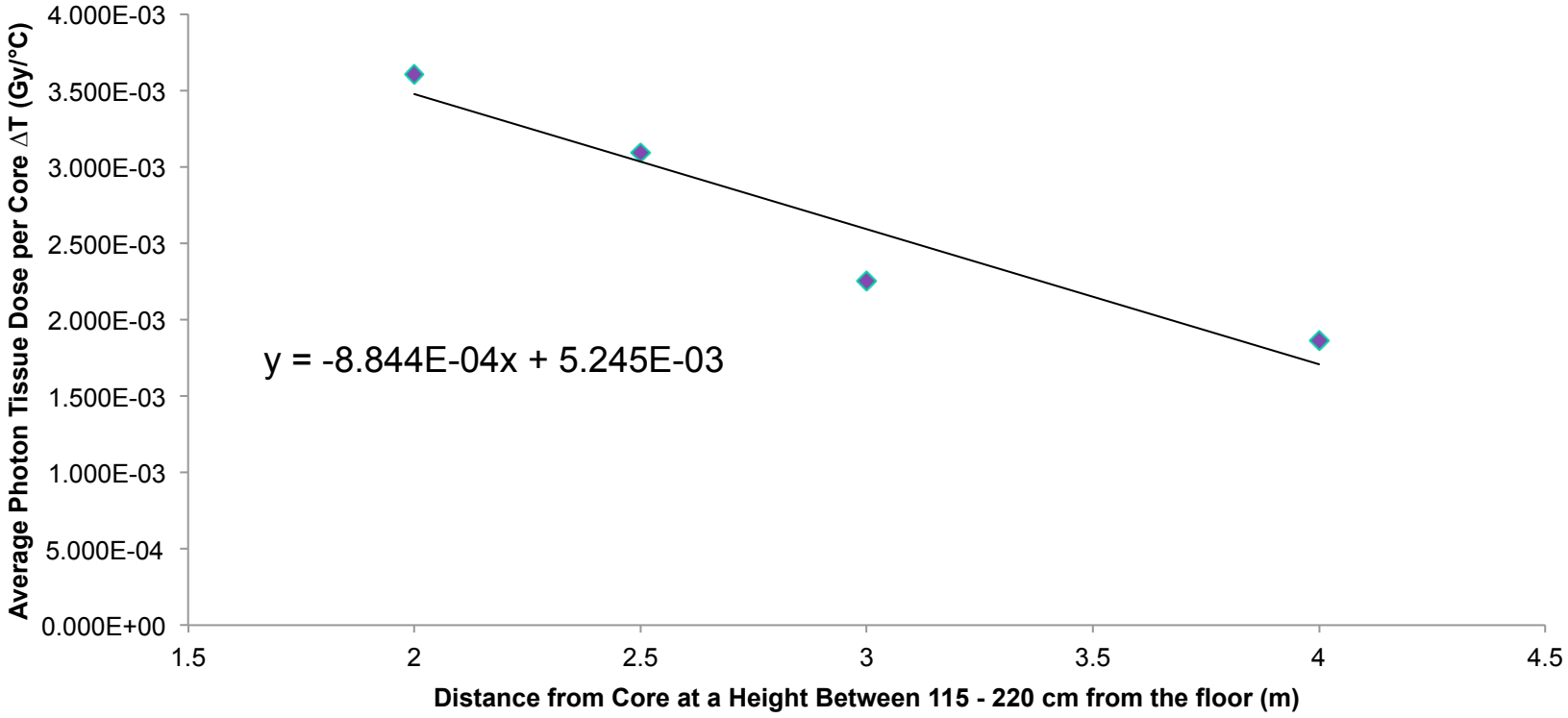
Correction of PBSS 1eV to 1MeV neutron fluence for bursts greater than 70°C



Correction of PBSS thermal neutron fluence for bursts greater than 70°C



Measured and projected gamma doses



- Based on CaF measurements of Gamma dose
- LLNL gamma doses were within 15% of CaF doses

Neutron Tissue KERMA Average Conversion Factor (CF)

KERMA conversion factors are fairly consistent among all literature references.

Averaging CFs from all references relative to the PBSS measured Godiva spectra is the reasonable approach to establishing a consensus value.

Difference from average for given references sources

Position	Singh	IAEA 211	IAEA 180	ICRU 13	ICRU 26	ICRU 46/33	ICRU 46/44 Male	ICRU 46/44 Female	ICRU 63
1	-0.36%	2.96%	0.12%	2.26%	0.60%	-3.44%	-4.58%	0.10%	2.35%
2	-0.36%	2.96%	0.12%	2.26%	0.60%	-3.44%	-4.58%	0.10%	2.35%
3	-0.36%	2.97%	0.11%	2.25%	0.59%	-3.44%	-4.58%	0.10%	2.37%
6	-0.51%	3.02%	0.11%	2.10%	0.55%	-3.44%	-4.57%	0.12%	2.61%
4	-0.48%	2.99%	0.12%	2.15%	0.56%	-3.44%	-4.57%	0.12%	2.55%
5	-0.51%	3.00%	0.13%	2.13%	0.56%	-3.44%	-4.57%	0.12%	2.59%
7	-0.55%	2.99%	0.13%	2.12%	0.56%	-3.44%	-4.56%	0.15%	2.61%
8	-0.58%	3.00%	0.13%	2.10%	0.55%	-3.44%	-4.56%	0.15%	2.65%
9	-0.60%	3.00%	0.13%	2.08%	0.55%	-3.44%	-4.56%	0.16%	2.68%

*based on PBSS neutron spectra

Observed differences for dose conversion factors are more significant.

	ANSI 13.3-2013				
Position	**Dp(10)/Φ**	**D*(10)/Φ**	**Auxier et. al. Element 57**	**IAEA 211**	**NCRP 38**
1	7.24%	3.56%	-7.97%	2.71%	-5.55%
2	7.18%	3.51%	-8.09%	3.07%	-5.67%
3	7.17%	3.46%	-8.06%	3.04%	-5.62%
6	7.02%	2.87%	-7.87%	3.08%	-5.10%
4	6.86%	2.81%	-7.76%	3.15%	-5.05%
5	6.87%	2.76%	-7.78%	3.17%	-5.03%
7	6.42%	2.18%	-7.35%	3.15%	-4.40%
8	6.46%	2.15%	-7.38%	3.15%	-4.39%
9	6.35%	1.97%	-7.27%	3.16%	-4.21%

ANSI 13.3 performance testing criteria for criticality accident dosimeter systems

Total absorbed dose range	B
0.1 to 1 Gy (10 to 100 rad)	±50%
1 to 10 Gy (100 to 1000 rad)	±25%
>10 Gy (1000 rad)	Must give positive indication of >10 Gy (1000 rad)

prefer to keep errors of known dose values to within ±5%

The Answer Key

An answer key based on burst temperature provides the known KERMA and dose values for positions as well as averages for distances (2, 2.5, 3, and 4 m)

		Enter New Burst Temperature	122	°C				
		Total Fluence	**Tiss. KERMA Dose**	**ANSI 13.3 Dp(10)**	**ANSI 13.3 D*(10)**	**Auxier et. al. Element 57**	**IAEA 211**	**NCRP 38**
Distance	**Position**	**n/cm²**	**(Gy)**	**(Gy)**	**(Gy)**	**(Gy)**	**(Gy)**	**(Gy)**
2	1	1.01E+00	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx
2	2	1.97E+00	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx
2	3	1.53E+00	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx
2.5	6	1.30E+00	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx
3	4	1.19E+00	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx
3	5	1.21E+00	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx
4	7	8.58E-01	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx
4	8	8.85E-01	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx
4	9	8.88E-01	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx

Note: the table above is an example, any values provided are not real

Any Questions?